of ephemeris and get first corrections to the elements of the orbit. From these compute not only the places corresponding to the normal date, which are necessary for a further correction, but a place on each side of this, and from the differences between these places and those given by the original ephemeris deduce a value of c. If now we use this in the expression

$$a = \text{mean of errors of ephemeris} - \frac{\Sigma(t)}{n} b - \frac{\Sigma(t^2)}{n} c$$

instead of the value of c from the observations themselves, we shall get a good normal without the labour of computing an entire ephemeris and comparing it with observation.

Thus suppose we compute the place of the object for p days before and after the normal date as well as for that date, and the difference between the ephemeris and these revised places be on the three dates e_1, e_0, e_2, we may put

$$e_1 = a_1 - b_1 p + cp^2$$
$$e_0 = a_1$$
$$e_2 = a_1 + b_1 p + cp^2;$$

whence

$$\tfrac{1}{2}(e_1 + e_2) = a_1 + cp^2, \text{ and}$$
$$c = \frac{1}{p^2}\{\tfrac{1}{2}(e_1 + e_2) - e_0\}.$$

It is needless to compute b_1 and a_1 because an error in b will have little effect; and, moreover, owing to the change in the elements, b and b_1 would not probably be alike; but this value of c will be better than any value deduced directly from the observations.

Of course the corrected normal places would be used for the second correction of elements, and probably it would always suffice to ignore the value of e in getting places for the first investigation.

One advantage of this procedure would be that it would generally suffice to use three places of decimals in the equations of condition, and one less than Oppolzer uses all through the rest of the work, which, indeed, could now be carried out with the slide rule with much saving of labour.

On the Orbit of Comet I. (Sawerthal) of 1888. By Lieut-General J. F. Tennant, R.E., F.R.S.

This comet was discovered at the Cape of Good Hope on the morning of February 19, 1888, by Mr. Sawerthal of the Observatory. Observations were of course very frequent in the earlier part of its course, but fell off greatly as other new objects called for attention, though it continued visible as a faint object till the middle of August of that year.

From Mr. Tebbutt's observations on February 27, March 6, and March 14, I deduced a parabolic orbit; and by comparing this with a large number of observations I deduced normal places of the comet. Of course individually the places were not very accurate; but I believed that by multiplying the observations used I should get fair normals; and, as they came from all parts of the world and were by many observers, I should get rid of those errors which must arise from low magnifying power, difficulty of estimating the centre, and also from the centre of luminosity not always coinciding with the centre of mass.

Each normal place depends on all the published observations I could find during about a fortnight, and, in the case of the last place, observations kindly communicated by the Astronomer Royal and the Radcliffe Observer, which have been since published; some, which seemed manifestly erroneous, I rejected without any attempt at correction. As to the rest, no attempt was made to weight them. Paris mean time has been used in the calculations as most convenient for the *Connaissance des Temps*, but I have now corrected the times of perihelion passage to Greenwich time. The dates &c. of the normals are

No. 1	for Feb. 25·5	P.M.T.	depends on	38 obs.	from	Feb. 18^{d}·6	to	Mar. 2^{d}·6
2	,, Mar. 18·5	,,	,,	37 ,,	,,	Mar. 13·3	,,	Mar. 22·7
3	,, Apr. 9·5	,,	,,	43 ,,	,,	Apr. 3·6	,,	Apr. 17·6
4	,, May 1·5	,,	,,	40 ,,	,,	Apr. 25·6	,,	May 8·6
5	,, May 24·5	,,	,,	28 ,,	,,	May 17·5	,,	May 31·5
6	,, June 13·0	,,	,,	22 ,,	,,	June 7·4	,,	June 19·5
7	,, July 7·0	,,	,,	18 ,,	,,	June 27·4	,,	July 16·4

After this last date I found few observations, and the faintness of the comet made me feel that no confidence could be placed in a normal at a later date.

The first points to be considered when combining into one result observations extending over so considerable a time was the law which should be considered as governing the errors of the ephemeris. Representing this by $a+bt+ct^2$, it is evident that if c be really too small to be determined by the observations, then we should be liable to injure the value of a (which is the correction of ephemeris required) by determining it; on the other hand, if its effect be omitted when really sensible, a would be similarly affected. On examining the apparent course of the comet it seemed that the first five places all lay nearly on a great circle, but that the course was markedly curved later; I therefore concluded that probably c would only require determination for the 6th and 7th places, when, too, the apparent velocity was rapidly changing. I, however, have actually determined a for each date both with and without the use of c. The places with c used I shall call the *first hypothesis*; those without c, the *second*.

The differences between the observed and computed places for each observation on one day were combined to form a mean error at the mean of the times of observation, and to this was assigned a weight equal to the number of observations, and an equation of condition formed to represent it. The solution of these equations by the method of least squares would have been troublesome. I therefore adopted the method described by Leverrier in the latter part of Art. 34, p. 136, of the first volume of the Paris *Annales*, using all the equations to form the a equation, and in forming the b &c. equations rejecting all those in which the coefficient of the unknown quantity is less than $\frac{1}{3}$ of its greatest coefficient; a procedure which saves much trouble without material loss of accuracy.

A first correction of the elements was then obtained on the first hypothesis, with the following result:—

Perihelion Passage 1888, March $17^{d}\cdot002261$ G.M.T.

$$\left.\begin{aligned} \Omega' &= 273^{\circ}\ 31'\ 25''\cdot37 \\ \pi' &= 237\ \ 14\ \ 12\cdot32 \\ \omega' &= 323\ \ 42\ \ 46\cdot95 \\ \iota' &= \ \ 37\ \ 46\ \ 03\cdot22 \end{aligned}\right\} \text{Equator and Equinox of } 1888\cdot0.$$

$$\log q = 9\cdot8443452$$
$$e = 0\cdot9958799.$$

Computing the places at the normal dates, I obtained the following system of errors:—

	$\alpha_0 - \alpha_c$ 1st Hyp.	$\alpha_0 - \alpha_c$ 2nd Hyp.	$\delta_0 - \delta_c$ 1st Hyp.	$\delta_0 - \delta_c$ 2nd Hyp.
	$''$	$''$	$''$	$''$
1	−1·6	+ 2·1	−1·8	−1·3
2	+0·6	+ 4·4	+2·2	+1·9
3	+6·1	+ 0·2	−3·3	−0·9
4	+0·4	+ 3·6	+1·3	−2·7
5	−4·9	− 2·2	−5·3	−3·3
6	−5·5	− 9·0	−2·0	−1·4
7	+7·7	+ 10·7	−4·2	−2·8

These results seemed to me to show that the conclusions I had drawn from the track of the comet were correct, and I proceeded to a second correction of the elements, using the errors of the second hypothesis for the first five dates, and those of the first for the 6th and 7th.

The resulting elements and their probable errors are—

Perihelion Passage, March $17^{d}{\cdot}001823 \pm 0^{d}{\cdot}000511$ G.M.T. or
March 17 $0^{h}\ 02^{m}\ 37^{s}{\cdot}5 \pm 35^{s}{\cdot}5$ G.M.T.

$$\left.\begin{array}{l} \Omega' = 273^{\circ}\ 31'\ 26''{\cdot}29 \pm 6''{\cdot}13 \\ \pi' = 237\ \ 14\ \ 06{\cdot}81 \pm 6{\cdot}13 \\ \omega' = 323\ \ 42\ \ 40{\cdot}52 \pm 8{\cdot}67 \\ \iota' = \ \ 37\ \ 45\ \ 59{\cdot}07 \pm 2{\cdot}83 \end{array}\right\} \text{Equator and Equinox of } 1888{\cdot}0.$$

$$\log q = 9{\cdot}8443367 \pm 0{\cdot}0000042$$
$$e = 0{\cdot}9958467 \pm 0{\cdot}0000438$$

or if referred to the ecliptic—

$$\left.\begin{array}{l} \Omega = 245^{\circ}\ 22'\ 56''{\cdot}0 \\ \pi = 245\ \ 18\ \ 26{\cdot}9 \\ \omega = 359\ \ 55\ \ 30{\cdot}9 \\ \iota = \ \ 42\ \ 15\ \ 10{\cdot}0 \end{array}\right\} \text{Equinox } 1888{\cdot}0.$$

The period of revolution is $2182{\cdot}3 \pm 34{\cdot}6$ years, and the probable error of an element of normal place is $2''{\cdot}20$ on a great circle; which shows that the mode of determining normals is satisfactory. All the equations of condition were considered of the same weight.

The large inclination of the orbit of this comet places it beyond the action of the outer and larger planets; but it will be seen that the perihelion and node are almost coincident; at the time of perihelion, too, the comet is only $0{\cdot}027$ (in parts of the Earth's mean distance from the Sun) from the orbit of *Venus*; so that if that planet had been in conjunction with the comet when in perihelion, it would have exercised on the comet a force $\frac{1}{270}$ of the solar attraction. It seems possible, therefore, that we owe this member of our system and the present form of its orbit to the action of *Venus* at some remote date.

On the Value of a Scale of Density on a Photograph.

By Captain W. de W. Abney, C.B., R.E., F.R.S.

In the last three eclipse expeditions which have been sent out from England under the auspices of the Royal Society it has fallen to my lot to have a good deal to say on the photographic arrangements, and at the last expedition to Grenada I devised a means of visually ascertaining the comparative brightness of the corona at different points in its surface. It struck me at the time how valuable it would be if, instead of eye measurements, the photographed image could be utilised, as then there would